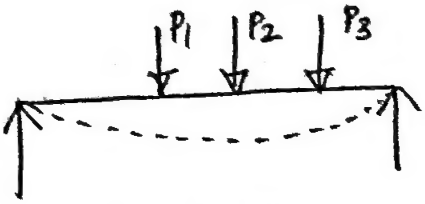
Beams



Design

Shear force, Bending Moment } Internal stresses

Deflection ← Response

Strength criterion → Shear force, Bending Moment

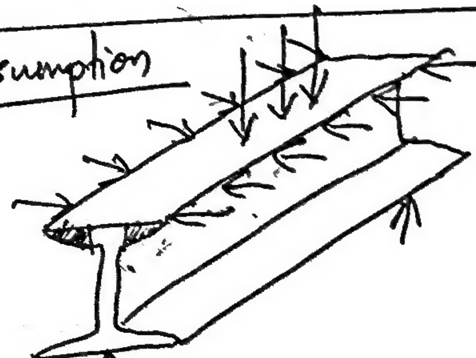
Serviceability criterion → Deflection

Plastic Analysis

Plastic ✓

Compact ✓

Assumption

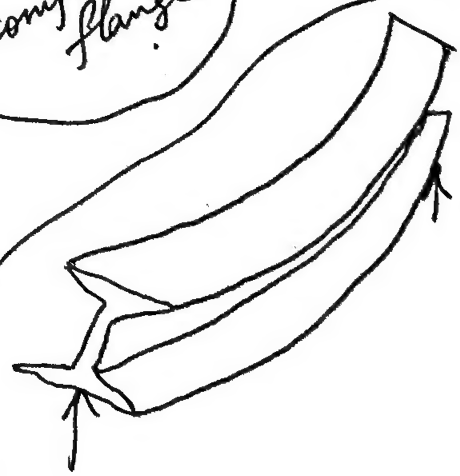


Lateral supporting or Lateral restraint

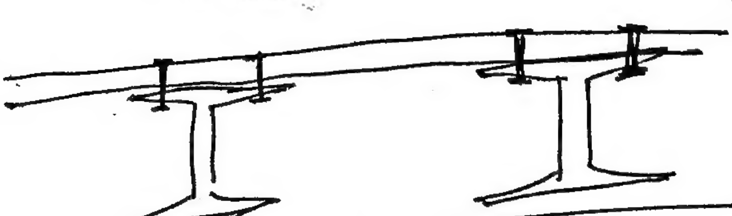
local buckling in compression flange ← to be prevented

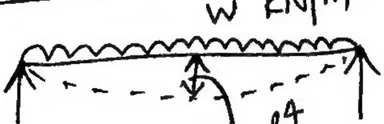
Those beams in which the compression flange is lateral supported throughout the entire length of beam

⇒ Laterally Supported Beams

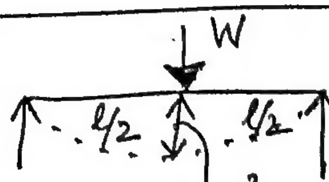


Lateral Torsional Buckling

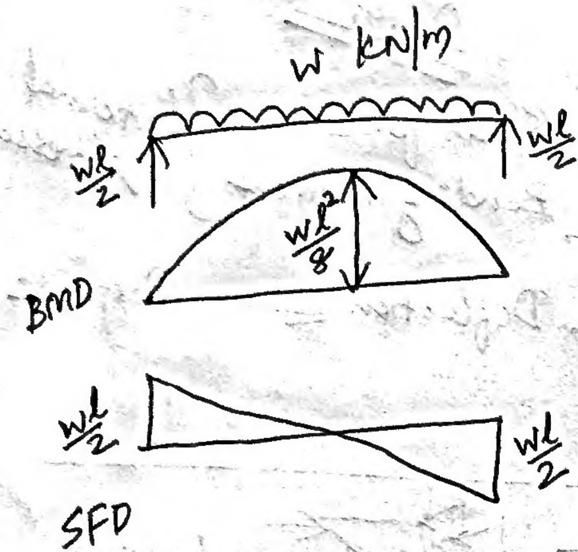


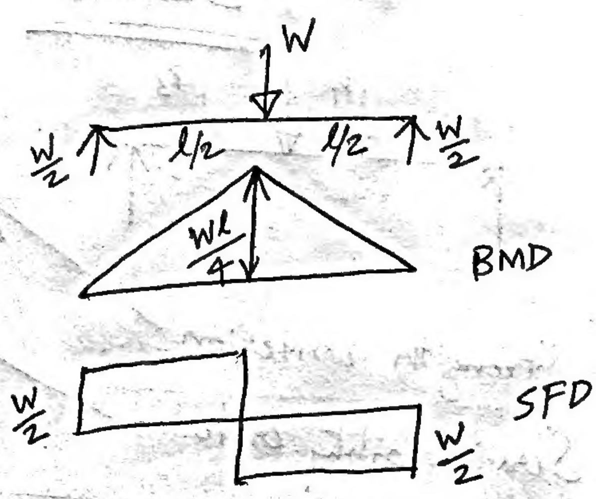


$$\frac{5wl^4}{384EI}$$



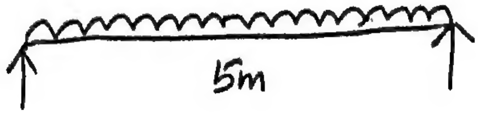
$$\frac{Wl^3}{48EI}$$


w kN/m
wl/2
wl/2
wl²/8
BMD
wl/2
wl/2
SFD


W
W/2
l/2
l/2
W/2
Wl/4
BMD
W/2
SFD
W/2

Q. Design a simply supported beam of span 5m carrying a reinforced concrete floor capable of providing lateral restraint to the top compression flange, subjected to UDL of 20 kN/m imposed load and 20 kN/m dead load. Assume Fe410 grade steel.

Ans: Simply supported beam



$LL = 20\ kN/m$
$DL = 20\ kN/m$ } UDL

Laterally Supported Beam $\longrightarrow$ To be designed.

(Fe 410 grade steel) $\longrightarrow$ min $f_y = 250\ N/mm^2$

I Calculation of factored loads:

factored $DL = 1.5 \times 20 = 30\ kN/m$

factored $LL = 1.5 \times 20 = 30\ kN/m$

factored self weight beam (approx.) $= 1.5 \times 1\ kN/m = 1.5\ kN/m$

Total factored load $= \underline{61.50\ kN/m}$

II Moment to be resisted by the beam

$$M_u = \frac{wl^2}{8} = \frac{61.50 \times 5^2}{8} = \underline{192.19\ kNm}$$

III Choosing a suitable beam

$$M_d = \frac{\beta_b Z_p f_y}{\gamma_{mo}} \quad (Cl.\ 8.2.1.2)$$

Plastic section modulus

$$Z_p = \frac{M_d\ \gamma_{mo}}{\beta_b\ f_y} = \frac{192.19 \times 10^6 \times 1.1}{1 \times 250}$$

$$= \underline{846 \times 10^3\ mm^3} = \underline{846\ cm^3}$$

Choosing ISLB 350 section (from Annex H)

self wt = 49.5 kg/m = 495 N/m = 0.495 kN/m

A_g = 63.01 cm^2

depth = 350 mm

flange width = 165 mm

flange thickness = 11.40 mm

web thickness = 7.40 mm

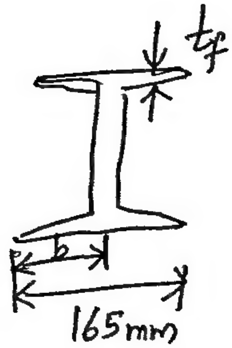
$Z_e = 751.9\ cm^3$

$Z_p = 851.1\ cm^3$

IV Classification of section — from Table 2

flange

$$\frac{b}{t_f} = \frac{82.5}{11.4} = 7.24$$



$b = \frac{165}{2} = 82.5$ mm

If plastic $\rightarrow$ $9.4\epsilon = 9.4 \times \sqrt{\frac{250}{f_y}}$

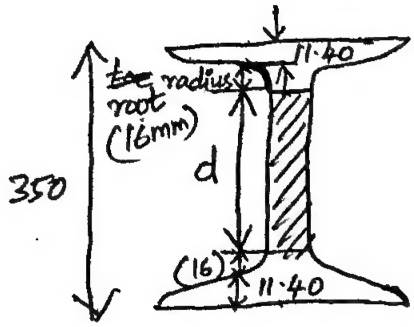
$$= 9.4\sqrt{\frac{250}{250}}$$

$$= \underline{\underline{9.4}}$$

$\therefore \frac{b}{t_f} < 9.4\epsilon \Rightarrow$ Compression flange is plastic section

web

$$\frac{d}{t_w} = \frac{350 - 2(11.40 + 16)}{7.40}$$



$$= \frac{295.20}{7.40} = 39.9$$

If plastic $\rightarrow$ $84\epsilon = 84\sqrt{\frac{250}{f_y}}$

$$= 84\sqrt{\frac{250}{250}} = 84$$

$\therefore d/t_w < 84\epsilon \Rightarrow$ Web is a plastic section

V Design Bending Strength (8.2.1.2)

for ISLB 350 section

$$M_d = \frac{\beta_b Z_p f_y}{\gamma_{mo}} = \frac{1 \times 851.1 \times 10^3 \times 250}{1.1}$$

$$= 193.4 \text{ kNm}$$

Since $M_u < M_d \Rightarrow$ Beam is safe

$$\frac{1.2 Z_e f_y}{\gamma_{mo}} = \frac{1.2 \times 751.9 \times 10^3 \times 250}{1.1} = 205 \text{ kNm}$$

Since $M_d < \frac{1.2 Z_e f_y}{\gamma_{mo}} \Rightarrow$ This is safe in resisting irreversible deformations.

VI Design shear strength of beam (Cl. 8.4)

$$V_d = \frac{V_n}{\gamma_{mo}} = \frac{V_p}{\gamma_{mo}} = \frac{A_v f_{yw}}{\sqrt{3}\,\gamma_{mo}} = \frac{h\, t_w f_{yw}}{\sqrt{3}\,\gamma_{mo}}$$

$$= \frac{350 \times 7.40 \times 250}{\sqrt{3} \times 1.10} = 339.85 \text{ kN}$$

For SSB subjected to UDL, factored shear to be resisted $V_u = \frac{wl}{2}$

$$= \frac{61.5 \times 5}{2}$$

$$= 153.75 \text{ kN} < V_d$$

$\therefore$ Safe in shear

$$0.6\,V_d = 0.6 \times 339.85 = 203\ kN$$

$$V_u < 0.6\,V_d \Rightarrow \underline{\underline{\text{Safe}}}$$

VII Deflection check.

Max. Deflection in this beam $= \dfrac{5wl^4}{384EI}$

$$= \frac{5 \times 61.5 \times 5^4}{384 \times 2 \times 10^8 \times 13158 \times 10^{-8}}$$

$$= 0.019\,m$$

$$= \underline{\underline{19\ mm}}$$

Permissible deflection (Pg 31 Table 6)

$$= \frac{\text{span}}{240}$$

$$= \frac{5}{240} = 0.021\,m$$

$$= \underline{\underline{21\ mm}}$$

Serviceability condition for deflection is satisfactory

$$2 \times 10^5\ N/mm^2$$

$$\frac{2 \times 10^5 \times 10^{-3}\ kN}{10^{-6}\ m^2}$$

$$2 \times 10^5 \times 10^6 \times 10^{-3}$$

$$= 2 \times 10^8\ kN/m^2$$

$$I = 13158\ cm^4$$

$$= 13158 \times (10^{-2})^4$$

$$= 13158 \times 10^{-8}\ m^4$$